Animal Responses to the Environment: The Eye and Ear

Terminology & definitions

Photoreceptors: Specialized receptors to receive the stimulus of light and convert it to an impulse. Photoreceptors in the retina of the eye are called rod and cone cells.

Refraction: To bend light – refraction takes place when light passes through a lens that is bent by a convex [ ] shape or a concave [ ] shape.

Stereoscopic vision: Also known as binocular vision - to see with two eyes, where each eye will produce a slightly different image of the same object and allows us to judge distance, depth and size of an object.

Accommodation: The ability to change the focal length of the object by changing the convex shape of the lens to assist with focussing on a near or distant object.

Myopia: Short-sightedness caused by a cornea that is too rounded so the image falls short of the retina.

Hypermetropia: Long-sightedness caused by a lens that cannot become rounded enough to refract light so the image falls behind the retina.

Mechanoreceptors: The Organs of Corti are receptors located in the cochlea of the ear, which are stimulated by sound waves and convert the sound waves into impulses.

Ossicles: Three little bones called the hammer, anvil and stirrup located in the middle ear and that function to amplify sound.

Otis media: inflammation and infection of the middle ear which causes pressure on the eardrum.

X-planation / Key Concepts / Diagram

The Human Eye:

Sight is perceived by the occipital lobes of the brain. There the impulses are interpreted, and the brain sends responses.
Animal Responses to the Environment: The Eye and Ear

Path of Light:
- Light rays pass from an object to the eye, through the transparent convex cornea, aqueous humour, the biconvex lens and vitreous humour.
- As the light rays pass through the curved surfaces of the cornea and the lens, light is refracted (bent).
- The lens refracts the light rays and forms an inverted (upside-down) image on the retina, bringing the image into focus by making fine adjustments.
- The rod and cone cells (photoreceptors) are stimulated by the light rays and convert the stimulus into impulses.
- These impulses are transmitted along the optic nerve across the optic chiasma (cross-over) so that impulses enter the lower visual centres on opposite sides of the mid-brain at the occipital lobes.
- The upright images are interpreted for size, shape and colour of the object that was seen.

Accommodation

Binocular vision means to see with TWO eyes (bi = two). The image from the left eye is always slightly different to the image from the right eye. The two images join in the brain (occipital lobes) and results in stereoscopic vision, which allows us to judge distance, depth and size of objects. The eyes can change the convex curve of the lens and therefore the focal length. This process is termed accommodation.

Near vision (round lens) - When viewing an object at a distance of less than 6 metres:
- The ciliary muscles contract, causing the ciliary body to move closer to the lens.
- This causes the tension on the suspensory ligaments to slacken.
- This results in tension on the lens being released.
- The lens becomes more convex and rounded, increasing the refractive power of the lens.
- The focal length decreases, bringing the object into focus onto the yellow spot of the retina.

Distant vision (long lens) - When viewing an object at a distance of more than 6 metres:
- At rest, the eyes are set for distant vision. (When people daydream, they have a faraway look because their eyes are set for distant vision.)
The ciliary muscles relax, causing the ciliary body to pull back from the lens. This causes the tension on the suspensory ligaments to increase, so they become taut (pull tight). This results in the lens pulling to a longer, thinner shape (less convex), decreasing the refractive power of the lens. The focal length increases, bringing the object into focus onto the yellow spot of the retina.

Pupillary mechanism (reflex)
The pupillary mechanism is a reflex action regulated by the Autonomic Nervous System, to prevent excess light from passing into the eye at one time. Excess light will cause damage to the retina and the photoreceptors (rod and cone cells). The iris controls the amount of light that enters the eye by controlling the size of the pupil. The circular and radial muscle fibres in the iris regulate the size of the pupil.

In bright light the circular muscles contract and the pupil constricts (gets smaller). The radial muscles relax.

In dim light the circular muscles relax and the pupil dilates (gets larger). The radial muscles contract.

Front view of iris to show the pupillary reflex
Animal Responses to the Environment: The Eye and Ear

Visual defects:

**Short-sightedness**

This is also called **myopia** or nearsightedness. It is a refractive defect where the image focuses **in front** of the retina because the cornea is **too rounded**. Distant objects are seen as blurred. Myopia may be **genetic** or overstraining of the eyes over a long period. Glasses and contact lenses that are concave ([]) are prescribed to **reduce refraction**. **Refractive surgery** may be an option, where the cornea is reshaped to flatten it and so decrease refraction.

**Long-sightedness**

This is also called **hypermetropia** or farsightedness and a refractive defect where the image focuses **behind** the retina. The person will not be able to see objects when they are close by, as the images are blurred. This condition is caused by the following:

- An eyeball that is **too short** (genetic) – corrected using convex lenses ([]).
- When the lens **cannot become round** enough during accommodation – corrected using convex lenses ([]);
- A cornea that is **too flat**: Refractive surgery is performed in extreme cases.

**Correction of visual defects**

![Diagram of Distant and Near Vision](image)

- **Distant vision** (long-sightedness)
  - Eye ball shape is **too rounded**
  - Image falls past focal point for near objects
  - Converging lens (convex)
  - Long-sightedness can be corrected by using a converging lens

- **Near vision** (near-sightedness)
  - Eye ball shape is longer than normal
  - Image falls short of focal point for distant objects
  - Diverging lens (biconcave)
  - Near-sightedness can be corrected by using a diverging lens
Astigmatism: This is an optical defect that results in blurred vision caused by an irregular curvature of the cornea or the lens so the eye has different focal points that occur in different planes. Glasses and hard contact lenses correct the irregular focal points.

Cataracts: This is the clouding of the lens when the lens cortex liquefies to form a milky white fluid. Cataracts must be removed surgically.

The Human Ear

The ears are the sense organs for hearing with mechanoreceptors in the cochlea of the ear that are stimulated by sound waves, which are converted to impulses. The impulses are transmitted via sensory neurons to the auditory centre in the cerebral cortex of the brain where they are interpreted. The ears are also the organs for balance and equilibrium. These impulses are transmitted via sensory neurons to the cerebellum where they are interpreted to ensure balance and equilibrium.

Path of Sound

Sound waves move from the vibrating source (for example, a person talking or a car driving past) in horizontal waves. Humans hear sounds with a vibration frequency of between 16 and 20,000 Hz.

- Sound waves are collected by the pinna and passed down the external auditory canal.
- The vibrations reach the eardrums ( tympanic membranes).
- The eardrum vibrates according to the frequency of the sound waves.
The vibrations are transmitted to the three ossicles (the hammer, anvil and stirrup) in the middle ear, to amplify the vibrations. The stirrup passes the vibration through the oval window, into the inner ear. The oval window vibrates and causes wave movements in the liquid of the perilymph. The wave movements are transferred to the endolymp inside the cochlea. The hair cells of the organs of Corti (the mechano-receptors) brush or bend against the membranes, which converts the mechanical stimulus of the sound wave into an impulse.

The impulse is passed through the auditory nerve to the auditory centre in the cerebral cortex of the brain. The sensation of sound is perceived and interpreted by the cerebral cortex. Excess vibrations are passed out through the round window, to prevent sound pressure and echoes.

Balance and equilibrium: is controlled by the semi-circular canals, the utriculus and the sacculus that contain receptors. The receptors will convert the stimuli of balance, equilibrium and pressure into impulses and send them to the cerebellum.

Hearing defects:
Middle ear infection: also termed otitis media and refers to an inflammation of the middle ear. When the middle ear becomes infected by bacteria, there is extreme pain as pressure builds up behind the eardrum. The pressure is caused by pus, which collects in the middle ear cavity. The Eustachian tube becomes blocked so there is a lack of the ability to equalise the pressure on both sides of the eardrum. In some cases, the eardrum may burst and pus drains out of the ear. Antibiotics are generally prescribed. Severe scarring of the eardrum can affect the person’s hearing.

Deafness:
The terms ‘hearing impairment’, ‘hard of hearing’ or ‘deafness’ mean that the person has a loss of the ability to detect sounds either partially or completely. Deafness can be as a result of:
- Sensorineural hearing loss
- Noise-induced hearing loss
- Genetic hearing loss
- Diseases that can cause hearing loss or impairment
  - Measles
  - Meningitis
  - Autoimmune disease
  - Mumps
  - Foetal alcohol syndrome
  - Syphilis – the foetus is infected by the infected mother
- Physical trauma

Hearing aids and cochlear implants:
A hearing aid is an apparatus that is worn in or behind a person’s ear. The apparatus amplifies sound, so that the person is able to hear better. A cochlear implant is a surgically implanted electronic device that stimulates the auditory nerves with an electronic field, inside the cochlea.

Link between hearing defects and speech disorders:
Animal Responses to the Environment: The Eye and Ear

When babies and toddlers are unable to hear properly or their hearing is impaired in any way, it will affect the development of speech. Humans learn to talk by mimicking the sounds that they hear. When a person cannot hear the sounds of the words, it is difficult to learn to talk. The sound vibrations made in the throat of a talking person are mimicked. Deaf people succeed in mastering spoken language to varying degrees, but the sounds that are made are different to that of hearing people. To overcome this challenge, a language of signing with the hands has been developed to assist deaf people to communicate effectively.

X-ample Questions

QUESTION 1:
(Taken from Bios best 2008 Grade 12 Biology)

The the diagram below that represents a section through part of the human eye.

![Diagram of the human eye with numbered parts 1 to 8]

1.1. Supply labels for the parts numbered 1, 3 and 5.  
1.2. Supply the number and name the part that controls the amount of light that enters the eye.  
1.3. Mention the changes that the part names in Question 3.2 will undergo when exposed to bright light.  
1.4. List one function for each of parts 4 and 7.  
1.5. Supply the number and the name of the part that is responsible for the accommodation of the eye.  
1.6. Explain the changes that will take place when the part named in Question 3.5 views an object closer that 6m.
Animal Responses to the Environment: The Eye and Ear

QUESTION 2:
(Taken from DoE May/June 2008 Paper 2)

Study the following diagram of the human ear and answer the questions that follow.

2.1 Identify parts B and G.  
2.2 State the function of each of parts C and E.  
2.3 Explain:
   a) Why you can often clear a buzzing/humming in the ear by swallowing
   b) Why the membrane labelled F is much larger than membrane C
2.4 A dog has lost part A in an accident. Part A is replaced with a stiff, non-elastic, solid plastic structure.
   a) Is the plastic structure as effective as the original ear of the dog?  
   b) Explain your answer to QUESTION 4.4 (a).
2.5 Explain how part D and the retina of the eye function in similar ways
2.6 Give ONE reason for part D being spirally shaped.

X-ercise
Various possible options are provided as answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number.

1.1. The tough, non-elastic tissue covering the outer portion of the eyeball is the ....  
   A choroid  
   B sclera  
   C conjunctiva  
   D iris
1.2. The shape of the lens in the human eye may be altered by the contraction or relaxing of the….
A  optic nerve  
B  muscles of the iris  
C  muscles of the ciliary body  
D  pupil

1.3. The sensation of sight in human beings originates in the ….
A  yellow spot  
B  optic nerve  
C  cerebrum  
D  retina

1.4. The following are part of the human eye:
1  cornea  2  lens  3  retina  4  iris  5  choroid
Which parts are respectively concerned with/in:
• Adjusting the focus?  
• Preventing internal reflection?  
• Recording changes in light intensity?
A  2, 4 and 3  
B  3, 4 and 1  
C  2, 5 and 4  
D  4, 1 and 5

1.5. When the tension of the suspensory ligaments in the human eye is slackened, the….
A  lens becomes less convex  
B  eye is focused for distant vision  
C  pupil enlarges  
D  lens bulges

1.6. When the pupil of the human eye constricts, the receptors and effectors are respectively the….
A  fovea centralis and ciliary muscle  
B  pupil and ciliary muscle  
C  pupil and radial muscles of the iris  
D  fovea centralis and the circular muscles of the iris

1.7. In accommodation of the human eye, the….
A  pupil enlarges  
B  ciliary muscles are involved  
C  suspensory ligaments are always in a state of tension  
D  circular muscles of the iris contract
Animal Responses to the Environment: The Eye and Ear

1.8. Images of objects less than 6m from the eye are clearly focussed onto the retina, when the….
A  ciliary muscles contract
B  pupil widens
C  muscles of the iris contract
D  curvature of the lens decreases

1.9. The optical disc where the fibres of the optic nerve leaves the eyeball, is the….
A  yellow spot
B  iris
C  blind spot
D  retina

1.10. Which of the following occurs when you look up from reading a book to look at a distant mountain on a clear, sunny day? The….
A  radial muscles of the iris contract
B  the pupil becomes more dilated
C  the ciliary muscles contract
D  the lens becomes thicker and rounder

Answers to the X-ercise Questions:

1.1. B
1.2. C
1.3. C
1.4. C
1.5. D
1.6. D
1.7. B
1.8. A
1.9. C
1.10. C